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*THE TRAINING OF TECHNICAL CHEMISTS.**

THE world's growth in manufacturing industries has increased enormously during the last century. This marked progress has resulted from a greater and more widely diffused knowledge of the sciences and their application. In this great advance the United States, aided by her wonderful and vast natural resources, has taken a very important part. In 1850 the value of manufactured products in the United States was $1,000,000,000. This has increased to the astonishing figure of $13,000,000,000 in 1900, while the value of unmanufactured agricultural products was estimated at $4,000,000,000.

In bringing about this increase, chemistry, assisted by engineering, has played a most important part. Our iron and steel industries, our whole field of metallurgy and, indeed, the majority of the great industries, would have remained in a crude, dormant state had it not been for the important work of the chemist and his more practical brother, the technical chemist. When we realize that the value of our manufactured products is three times as

* Paper read at the meeting of the New York Section of the American Chemical Society, February 5, 1904.

great as our agricultural products, it is plain to see the vast importance of the work of the chemist, and especially the technical chemist, in the successful operating, maintenance and improvement of our manufacturing industries.

It will be inferred from this statement that the number of chemists engaged in active work in this country has greatly increased. It is a fact that in the last thirty years they have increased in a proportion far beyond that of the increase in the value of manufactured products. It is interesting to note also that their importance is more and more recognized. Twenty years ago there were many establishments turning out manufactured products where no chemists were employed; these firms have since engaged chemists, with the result that a marked saving in the costs and improvement in the quality of the goods produced has been effected.

We are still very backward in this country in the employment of chemists when we compare our position with that of Germany, especially in the chemical industry itself. It is not uncommon in Germany for one concern (as in the Badische Anilin und Soda Fabrik) to employ over 400 chemists. We find in Germany that the highly educated technical chemists have done remarkable work in improving the chemical industrial condition of that country, placing it far ahead of all nations in many branches, such as the great coal tar color industry.

In the industrial strife which has been waging for some time between Germany and England, the former has gained on account of the fact that technical education is more widely diffused in Germany than in England. As an instance of this I quote an extract from the *Spectator* of December 5, 1903, being a reprint of a speech by Mr. Haldane before the Liberal League, wherein he explains that the industries of England have declined, not because the goods manufactured are kept out of foreign markets by protective duties, but because the goods themselves are inferior to those produced in foreign countries:

"The German manufacturers make a finer quality of cellulose than the English manufacturers. We have not yet succeeded in making it so white as they do, and for many of the uses to which celluloid is now put, whiteness is an essential quality. How did the German manufacturers set about obtaining this whiteness? 'Twelve of them,' says Mr. Haldane, 'combined together and put down £100,000, providing besides £12,000 a year, and in one of the suburbs of Berlin, near the great university, founded an institution which we have nothing like in this country. They had the most distinguished professor of chemistry they could get from the University of Berlin at the head of it; they gave him a large salary; they employed under him the best highly technically trained assistants that the university and the technical schools of Berlin could produce. * * * Whenever they had a problem, whenever they found that the British manufacturer was making his celluloid a little whiter, they said to their experts, 'Will you show us how to make ours whiter still?' The investigators were set to work and we were beaten nearly out of the field."

In this country there are numerous examples where the technical chemists have immensely improved manufacturing conditions either by lowering costs or by producing a higher quality of product. There is still much room for improvement, and I venture to say there is hardly a plant in the country turning out products requiring chemical skill where marked improvements could not be made by the very best work of technical chemists, in effecting changes that would reduce the cost of labor and

fuel, in recoveries from waste products or by producing better material.

Before deciding on the best methods of training our technical chemists, we must see that they are sufficiently educated in the proper lines to enable them readily to become technical chemists of great value. During my long experience in connection with chemical manufacturing and metallurgical work I have been forced to the full realization that the majority of chemists who are employed as analysts, technical chemists and as works or department managers, have perfected themselves in chemistry alone and seem to have neglected the importance of physics and engineering. If one wishes to achieve the greatest success in such work he should not undertake the problem at all unless he has made up his mind to perfect his mathematics and become thoroughly familiar with physics as well as mechanical engineering.

It seems a great mistake that the term technical chemist has been used in connection with chemists who are obliged to apply chemistry in manufacturing processes. It would have been better had they been called chemical engineers, for this might have induced the study of chemical engineering in the colleges many years ago. I feel certain that, had this been done, our industrial situation would have been much further advanced than at present, and the standing of practical chemists would have been higher and their value more highly esteemed than is the case. We do not speak of a metallurgist as a technical metallurgist, a miner as a technical miner, or an electrician as a technical electrician. The metallurgist is, properly speaking, a metallurgical engineer, the miner a mining engineer and an electrician who applies electricity, an electrical engineer. In all of these positions it is impossible to succeed without a full knowledge of mechanical engineering. The same is true in the application of chemistry. It would appear that when young men aspired to become chemists they looked upon the great chemists as supreme beings. They also considered mechanical engineering, with its machinery, machine shop, foundry, etc., as beneath the dignity of the chemist; they left college knowing nothing of mechanical engineering, and of course were totally unfit to take positions as works managers or wherever it became necessary to apply chemistry in a large way. I have known cases where young men, who were exceedingly clever as chemists, but totally ignorant of engineering and as unpractical as one could imagine, were placed at once in positions of practical responsibility in small chemical works. No more cruel act could possibly be done to the chemist. The business managers were not practical and had studied neither engineering nor chemistry. Of course many of the chemists who were placed in such positions proved utter failures, and for this reason many of the practical business men twenty-five years ago doubted the value of chemists in connection with manufacturing. Had these young chemists been chemical engineers and had the business managers received a moderate education in mechanical engineering and chemistry, the combination would have resulted in a marked success instead of failure.

When we notice the enormous field in manufacturing in this country one can not help feeling that the study of mechanical engineering should be very much more general than at present. I have known chemists who had not studied engineering, who, when placed on practical work, realized their deficiencies and took a course in mechanical engineering at night schools in order to enable them to properly apply their chemical knowledge. After men have gone through a regular course in chemical engineering they should be

trained, as far as possible, before leaving college in a thoroughly practical manner in the application of chemistry as well as in examples of engineering problems.

The greater the application of chemistry, the more important becomes the combining of mechanical training with chemical training. Our colleges should consider this matter more seriously than ever, and do their best to make the course in chemical engineering as complete and perfect in every way as possible. This is a duty they owe to our young men who desire to make a success in the great field of chemical engineering; it is a duty they owe to the manufacturers of this country who are doing their best to rival successfully the highest European competition and obtain our full share of the markets of the world for our manufactured products. Many of our manufacturers would receive the highly educated chemical engineer with open arms, and as a proof of their earnest belief in the importance of this matter they would gladly make necessary endowments to assist the colleges in carrying out this important work. The colleges should court their assistance by receiving all the practical suggestions that would enable them to readily turn out men so well educated and trained that they would very easily become valuable chemical engineers.

Chemical engineering necessitates a greater variety of engineering than all the other branches of engineering combined. In designing the apparatus that is employed in conducting the endless variety of chemical and metallurgical processes, every known metal and alloy is used in every conceivable variety or form. All kinds of brick are used, acid, basic, neutral and vitreous, glass, all sorts of pottery-ware, porcelain, stone, rubber, coke, asphalt, wood, cements, etc., and these in every combination and form which the best chemical engineering skill can devise to improve old methods and properly conduct new processes. In order to select the best material with which to carry on difficult problems, the chemical engineer must have a wide knowledge of the action of acids, alkalies and chemicals under all conditions of solution and heat, upon all known substances which could be employed to carry on the processes. Generally in new problems, carefully conducted investigations have to be made on a small scale, to show conclusively the best substances to be used.

In the designing and construction of plants and apparatus the chemical engineer has not only to select the most suitable material, but he must so carefully study the function of every detail of the apparatus to be used, that each part will successfully meet the full requirements. Each and every part must be proportioned to what it has to do; everything must be proportionately strong and large enough for the purpose, always avoiding unnecessary extremes in order to curtail the first cost of the plant. The desired end must be met in the simplest possible manner and the devices so arranged that while operating they will be so nearly automatic that good results will be achieved with the least possible labor. The plants must be so designed that the greatest yields will be obtained and the finest products turned out.

But after all this is done the chemical engineer will not be thoroughly skilful and up to date unless he designs every part of the apparatus so that it will last the longest possible time. Everything must be arranged so that when repairs are required they can be conducted with the least expense.

For the successful operating, maintaining and improving the condition of plants where chemical skill is employed, the manager or superintendent and his assistants

must be trained not merely in chemistry, but in mechanical engineering as well. Training in business and departmental management is also highly desirable. However perfectly a plant and its apparatus may be designed and erected, it will not necessarily give successful results unless every machine, furnace, still, condenser, tower, etc., is operated under the management of a man who is fully conversant with the function of every detail of the apparatus. In order to obtain in every way the best possible results, the superintendent is greatly handicapped if he has not received a full education and practical training in chemical engineering. Without the proper scientific knowledge that governs all the operations, he never fully understands the true reason for all the things that are done under his control. The inevitable outcome of such unintelligent management results in the continuance of a low standard of skill in all the working force under him. The apparatus is not run to the best advantage, thus lowering the quality and raising the cost of the goods produced. On the contrary, if the superintendent is properly educated in chemical engineering and has had a proper training as an assistant superintendent or practical investigator, and especially if he has a natural fondness for machinery and mechanics, then success will crown all his work. Whenever there is a difficulty—something breaks down and bad results follow—then he will at once clearly define the reason for the trouble and take the proper steps in completely correcting the evil. He gives true reasons for everything that is done in the various departments of the plant. He sees much going on that is unreasonable, and step by step he brings the unsatisfactory work up to a higher and higher standard. His assistants are chemical engineers, and he inspires great confidence and interest in them by a course of training that causes them to think and reason from every standpoint, so that before taking action, everything having an important bearing on the chemical, physical, engineering, business and labor sides of the problem in hand is most carefully considered.

By such a course of training the young men learn to think systematically and, guided by a master of the art, they rapidly learn to make the best use of their education in applying it to important practical work. It is quite natural for the impulsive youth to put into practice the first thought that comes to his mind. In the practical training that he should receive I must impress upon you the importance of making him consider every problem most carefully and from all sides, before taking action. In this manner he will acquire a habit of not acting quickly or without deep consideration. You will find that men who have thus been made to think and reason broadly and in a systematic manner, will put into practice what may be considered good sound judgment. Such men are bound to make a success in the practical application of their chemical engineering.

In a large chemical or metallurgical works, or any other establishment where the processes are controlled by chemical analysis and where the raw and finished products are bought and sold for values governed by analysis, it is necessary to have a well-appointed chemical laboratory. In large plants where many chemists are employed, an able chemist should be at the head of the analytical as well as the research laboratory; the chemists in the analytical laboratory are not always college graduates, as most of the work is of a routine nature, requiring great skill in manipulation but not necessarily an extensive knowledge of chemistry. These men, when confined to this work, have no opportunity to employ engineering skill ex-

cept in perfecting the apparatus used in making chemical analyses. It is of the utmost importance that their analyses are accurate and quickly performed. On very important work, such as analyses made for settlements on raw material and finished products, analyses are run in duplicate and settlements made on a split between the buyer's and seller's results. This competition encourages very accurate work on the parts of the analysts, and they become very skilful.

It is the custom in all well-managed industrial laboratories to investigate frequently the analytical methods used, in order to determine their accuracy, reliability, ease and quickness of performance. Old methods of analysis are thus improved, new methods invented and the new methods of others compared and adopted, if found the most suitable. For this reason it is not uncommon to find the most desirable analytical methods used in the laboratories of our important industrial establishments. The colleges would do well to look into these methods as far as possible, and thus keep abreast with the best practice to aid them in teaching analytical methods.

There is no reason why the training of analysts in large laboratories should not be of the highest order. It is a great mistake to allow the standing of the work done in these laboratories to run down. It is a grave error to economize too much in the laboratory by employing too few analysts and thus prevent the practical managers from receiving all the information required to control intelligently the various processes in the factory.

After men have been a few years in an industrial laboratory they, as a rule, desire positions in the works. It is the exception when we find a chemist from college who has studied mechanical engineering; for this reason only very few chemists become good candidates, qualified for giving proper attention to large factory processes where the many complicated devices require engineering as well as chemical skill. I have known many of the men in a laboratory to study mechanical engineering either at night schools or with correspondence schools. It would have appeared the part of wisdom for such men to have taken a course at college in mechanical engineering as well as in chemistry, thus fitting them for a wider field of work in their chosen vocation, and affording an opportunity to make greater advancements.

The future success of any well-established industrial institution of a chemical nature is in grave peril if it does not have an investigation or research department. The manager of this department must be by education a chemical engineer. He should have had much experience as a practical business manager of plants, and a direct acquaintance in the designing, reconstruction and repairs of the same. This department must have a properly equipped research laboratory. The head of this research laboratory must be possessed of very high attainments as a chemist and physicist, with a fair knowledge of mechanical engineering. His work through life will be stamped with the greatest success if he has been trained at college in methodical methods of thinking, as applied to original work, and to many examples of practical investigation and experimentation. The chemists under him should have received the same education and training at college. It is desirable that this department should have the capacity to investigate new processes that are presented, and if they look promising, a small working plant should be constructed and operated by them to prove fully the value of the method and to give the necessary practical data to be used in the designs of a large and fully equipped plant. This department will keep in touch with every-

thing that is published, in either technical journals or patent reports, having a bearing on the work under consideration. All the processes in the company's works will be carefully investigated by them, to locate and devise means for preventing losses in gases, liquid and solid waste material, and thus increase the yield of the useful products. They work up methods for making useful products from waste material. Much of their time is occupied in working up means for improving the quality of the various finished products. They are also busily engaged in working up new processes, putting the same into practice, and thus entirely supplanting the old methods.

It will be seen from these remarks that to become a skilful or trained investigator in a research chemical laboratory requires:

1. A proper education at college as a chemical engineer, especially full in chemistry.

2. Training at college in original thought as applied to practical investigation, and to working up and improving processes.

Some of you feel that it is a mistake to divide the work of one man between chemistry and mechanical engineering; that the chemist must be solely a chemist and the engineer an engineer alone. I admit that a very small proportion of the chemists have to devote all their time to pure chemistry, and in certain lines of theoretical and research work. The great majority of chemists in this country, however, are engaged in practical work where they need engineering assistance, and in such cases the chemist who is not an engineer would have to consult the engineer for practical advice, and the engineer seeks chemical assistance from the chemist and without a knowledge of chemistry obtains but little satisfaction.

My experience forces me to feel that a complete understanding of the various problems must come from a brain that can think in both chemistry and engineering. The dignity and fame of chemistry will not be injured by joining in close union with engineering. Indeed, the real value and glory of chemistry come from its application to useful products that add comfort and happiness to the human race. These applications can not be carried on without the aid of engineering.

Applied chemistry would be greatly benefited in this country if the colleges would come in closer touch with the manufacturer. The professors of chemistry and mechanical engineering would do well to study more carefully the educational requirements as found in some of our large works, where the advantages of a well-directed knowledge of chemical engineering are clearly shown. I am sure the broad-minded manufacturers would gladly cooperate in this important work, seeing plainly that it must result in a general advantage to our industries, and to the industry and prosperity of our whole country. The best way to carry on this work would be to employ a plan that has been in successful practice at Brown University for the last few years. They carefully select from their alumni a separate committee for each department of study. These committees visit the college once or more a year; they consult and exchange views with the heads of the departments they represent. Each member reports his recommendations to the chairman of his committee, who incorporates the same in his report to the president of the college. I am a member of the committee appointed to assist the chemical department of Brown University. I recommended to them to have a course in chemical engineering, and, indeed, outlined a four-year and a five-year course, giving the number of hours per week for each study.

The more perfectly and completely chemistry is applied by engineering assist-

ance, the greater will be the volume of manufactured products and the larger will be the field for chemistry. May Americans stand foremost among the nations of the world in turning out chemical engineers having such great ability that they can easily lead our manufacturers to an unapproachable pinnacle of greatness and perfection. May the chemists of the American Chemical Society ever be leaders in this great work, and may their name and fame remain to the end of time a living monument to industry, progress and prosperity.

J. B. F. Herreshoff.

DISCUSSION.

Mr. T. J. Parker.

It seems to me the keynote of the discussion was struck by one sentence in the address, which was to the effect that the marvelous development of industrial chemistry in this country is due to the work of the chemical engineer. I do not see from my standpoint how the dual existence of the engineer and the chemist is necessary for the higher development of the chemistry and mechanics of the industry committed to the charge of the competent technical chemist. The important question arises, therefore, What shall we do to properly equip the young men who are annually turned out from our technical schools and colleges?

From the experience of many here present they could no doubt tell you of men who have been brought up in mechanical pursuits, not as chemists, and whose practical knowledge of chemistry was acquired after they had left college, who have made very successful men, because they had mechanical ability to apply the investigations and discoveries of the scientific chemist to the requirements of the manufactures or arts under their charge. If the application of chemistry to manufacturing processes is desired, it is certainly necessary for these young men to have a knowledge of mechanics or engineering as well as chemistry, in order to apply it efficiently in our factories.

The opening for the industrial chemist in the next five or ten years is simply phenomenal, judging from what we have heard here to-night.

Mr. M. C. Whitaker.

On the technical staff of a manufacturing establishment you will find a civil engineer who lays out the grounds and devises new construction, and you will find a mechanical engineer who plans his boilers and his new engines; both of these men, in the opinion of the superintendent, are very important individuals. The electrical engineer sets up his dynamos and places his motors. He devises new and ingenious electrical apparatus, and he, in the mind of the superintendent, is also a very important individual. Now, when the processes connected with these manufacturing industries are referred to the chemist for improvement, he repairs to his laboratory, and we all know that he goes through some very serious, painstaking work. This work is not appreciated by the superintendent because he is not a chemist. What the superintendent asks for is actual merchantable results. The chemist is generally not a man who is capable of transmitting from a laboratory to a factory the ideas which he has developed. He is not educated in the engineering branches which have been so much emphasized here this evening. He should have a knowledge of electrical engineering and bring it to bear in the proper solution of problems coming before him. He should have such a knowledge of mechanical engineering as to bring to bear the best mechanical devices. Furthermore, and in my mind the most important of all, he should have that knowledge of getting along with

people so developed that, after he has prepared his plans and laid them out, he can get the help to bring about the results which he desires. This is a very important step, but the point I have tried to make is that the man must not only have the knowledge to develop new ideas, but he must have the knowledge to put them into practise. Now, we see that those men who have by themselves obtained this engineering knowledge, either before or after studying chemistry, are the men who make a fair success. Therefore, it seems to me very important that we should do all we can to help to produce the kind of a chemist that I have named—a chemical engineer. A man who has such a knowledge of chemistry, of electrical and mechanical engineering, of metallurgy and of the handling of men as will enable him to go into a laboratory and develop a process, and then put it into operation and deliver to his concern a merchantable result, will have that recognition on the payroll which he deserves. In other words, I think that these men, instead of being assistants in our manufacturing industries, will be leaders.

DR. WILLIAM MCMURTRIE.

Those of us who have had experience in the applications of chemistry in a large way have long recognized the truth that to be successful in the chemical industries in this country one must be at the same time a chemist and an engineer. One must know thoroughly not only the reactions involved in a particular industry and the laws of chemistry which govern them, but must have intimate acquaintance with the mechanical means whereby the reactions may be carried out in a large way.

I know full well that teachers in the educational institutions object that the time allotted for the training of young men for the chemical industries is too short to cover both the branches of work indicated, and most or all of us are prepared to admit that this objection is valid. Part of the difficulty is due to the fact that those charged with this training have to do with raw material in the student which is far too raw; that students present themselves not properly prepared for the work before them. I, therefore, believe that the training of the technical chemist, as well as that of every technical and professional man, should begin much earlier than the entrance to the technical school. It should begin even in the earlier grades of the primary school. Here the idea should be abandoned that the young minds are too immature for serious study and systematic work; that the children need to be amused rather than seriously educated; that they must be trained by kindergarten methods in lines which must later be traversed again in the serious struggle for education. And thus precious time is lost at the age when the mind is most pliable and receptive.

It would be far better to return to the old-fashioned methods of careful study of the three R's. The children should be taught first of all to read understandingly; to write clearly; to comprehend readily the great truths of literature and science, whether expressed orally or in print. Then they should have continued training in mathematics, the successful study of which involves careful and systematic thought and work. The result sought in any calculation in mathematics is always most definite, and the attainment of an accurate result involves careful attention to every detail. For this reason the study provides splendid preparation for successful work in any profession or in business, in the research laboratories or in the wider fields of the applications of science—the great manufacturing and engineering works.

So then let the children begin serious and systematic work early; let them be so trained that work once done need not be repeated; let them come to the technical

school with thorough and careful training first, in general culture, in language and literature, then in mathematics, and finally give them the advantage of the splendid courses provided in our technical schools in chemistry and engineering, and they will be prepared to meet effectively and successfully the great problems the chemical industries of the immediate future will have ready for them. That what is needed can be fully accomplished in a course of four years I doubt, but it may be helped by the preparation I have outlined. That the technical chemist of the future must know thoroughly the great laws of chemistry and at the same time be well grounded in the principles of engineering I do not doubt. And I am satisfied that justice to the young men, as well as to those who must employ them, demands that time for all the training I have outlined should be provided.

Professor Edward Hart.

It seems to me that we must in the first place reconcile ourselves to the idea of doing the best we can in four years. I am one of those who do not believe very much in post-graduate courses for chemical students. There are many who must have a post-graduate course, of course, but if you take the ordinary man and follow the history of such ordinary man, the man who passes through college and makes afterwards a success, you will find that very many of them were poor boys. They haven't the money to take more than a four years' course. If we are to turn out such men we must educate them, as far as we can, in four years. How are we going to do it? We must limit the number of our subjects. We must attempt and to a large extent succeed in teaching those things that we attempt to teach well and not attempt to teach too many things, and that involves a very careful selection of one part of the equipment to which I am sure too little attention is often paid, and that is those who take part in the work of teaching. I have had considerable experience in teaching. I have had very few assistants who did their work faithfully, very few. It is a very tiresome, thankless business to teach a lot of beginners, and it very seldom happens that before the end of two years of such work the man doesn't lose a part of his enthusiasm and do his work less well than it should be done. This work must be done well if we are to succeed in turning out the class of men that we want, and it is this work which determines very largely the quality of our product, for there is no truer thing in the world than that the student is largely the product of the self-sacrifice of his teacher. We must first teach the science of chemistry, so far as it is possible, and we must teach it thoroughly and well, because we can't go too far, and then we must teach engineering, because the chemical manufacturer is an artisan. He must be an artisan to a certain extent. I do not believe, however, that in the four years' course it will be possible to get into such a man more than the elements of engineering, but if these things are done well I am quite sure that the product will be quite different from the product that is turned out at the present time.

Professor W. A. Noyes.

The discussion thus far has dwelt almost exclusively upon the necessity that the chemist should know many things besides chemistry and especially that he should know mechanical engineering, and with all that phase of the discussion I most heartily agree.

With regard to the chemical side of the work we are in as great difficulty, almost, for lack of time as with regard to the accessory side of it. Chemical science has expanded enormously in the last twenty-

five or fifty years. It is as impossible to-day to know all chemical science, even in a general way, as it was fifty years ago to know all the sciences. Chemistry has so wonderfully developed in so many different directions that it is impossible for any one to cover the whole field. It is necessary, therefore, for the colleges to choose, in this large field, what shall be taught. Now, the basis of the training for the technical chemist and for the chemist of all kinds, must be a thorough training in analytical chemistry. I believe that the training in this particular field has become inferior to what it was a few years ago. Results that have come to my knowledge, and no doubt to the knowledge of others of you, during recent years, of the way in which chemists fail in comparatively simple analytical problems, show that the training of the chemist is not always what it should be. Another important question which comes before the teacher in the college is, How much training in industrial chemistry can be given to the student. It seems to me that comparatively little in that particular direction can be done, especially in a four years' course. It is important that the student shall have a thorough training in the fundamentals of the science and a thorough training in analysis. If that training is given, it is impossible to crowd into the four years' course any very considerable training in industrial questions. Another fact which makes any long or extended training in industrial questions inadvisable, as well as impossible, in the college course, lies in the extremely wide range of work in which these young men are going to engage, and, in a majority of cases, from the difficulty of telling what work the particular individual will do after he gets out of your hands. It is manifestly impossible, therefore, to train him for that particular field into which he will go. He must of necessity gain his special training in that field after he enters it.

PROFESSOR C. F. CHANDLER.

The difficulty is that our students come to us for four years. They never know what particular branch of chemistry they intend to pursue in after life. We are compelled, therefore, to treat them all substantially alike, and give them all substantially the same chemical education. Now, it is not possible in four years to do a great deal more than to lay the foundations of a chemical education, particularly if you want to devote some time to giving the students a good training in mathematics and various other branches which go to make up a complete chemical education. It seems to me as if the work of making the chemist was put entirely upon the instructors. The student expects the instructors to do the work. We suggested that we might increase the number of assistants, and let them make the analyses for the students. When I was a student I went into Wöhler's laboratory. He gave us a lecture every morning and we were expected to attend that lecture and make the most of it. Then we went into the laboratory. He handed me a piece of triphyline and said: 'I want you to get some lithia out of that.' He did not give me an hour's lecture and tell me how to make lithia and have me write it down. He gave me a piece of the mineral and I had to hustle and find the solution of the problem myself. He said: 'You have to make some lithia out of that, and after you have made up your mind, come to me and I will look over your proposition and see whether it is right.' That was the way chemistry was taught in Wöhler's laboratory. There was a small number of students and that method of instruction was carried out. We had seven hundred students working in our chemical laboratories

last year, and, of course, it is extremely difficult to give each student much personal attention. I think that one great difficulty is that somehow or other we have rather drifted into the condition that the student expects the professor to tell him everything that he has to do. I worked in Rose's laboratory for a year, making mineral analyses. He never told me how to make an analysis. He handed me a piece of mineral, samarskite, for example, and told me to find it out myself. I read everything I could find that had ever been written on the subject. I found out the best methods known for analysis. That was the system of those days. Now, the students expect us to stand up in the lecture room and tell them every step in the process of making an analysis. They must be told to weigh a gram and a half of this, and add this and that to it, so many cubic centimeters of this and so many of that, and they must do this, that and the other thing; and unless you tell the student every step of that kind, he can not make the analysis.

I quite agree with everything that has been said upon the subject of adding to the instruction of the chemist a sufficient amount of engineering to enable him to rise to the dignity of superintendent or manager of large works, but I do not think that can be done in a four years' course. If we train our men in analytical chemistry, in general chemistry, and in such an amount of industrial chemistry as can be taught in the lecture room, and such an amount of laboratory practice as can be carried on in university laboratories, and at the same time give them their thermodynamics and physics, and a certain amount of mineralogy, I think that is the best we can do.

Professor A. A. Noyes.

In the first place I would say, I believe that a distinct demand by manufacturers for men trained in both chemistry and chemical engineering will make it much easier to induce students to take the extra fifth year that is necessary in order to do anything like justice to these two subjects. I believe, too, that institutions can do a great deal in this direction by laying out a definite course of fifth-year work, leading to some higher degree; for when a definite course is offered there are more likely to be applicants for it than if it is only stated in a general way that there is an opportunity for advanced work.

I should also like to ask the question, whether manufacturers prefer a chemical engineer or an engineering chemist—that is to say, a man whose education is mainly upon the mechanical engineering side, with some knowledge of chemistry included, or a man whose main training is in chemistry, this being supplemented only by such an amount of mechanical engineering as can be worked in without serious detriment to his chemical knowledge? I think it should be borne in mind in answering this question that, if the chemical engineer is preferred, it would certainly mean a sacrifice of the power of attacking new problems on the part of our industrial chemists. The engineer is trained to put in application existing methods; and it seems to me that what is wanted of the factory chemist in this country is rather the power of solving new problems and of making improvements in processes—a power to be acquired far more by a good chemical training, which should include a large proportion of research and other work requiring independent thinking, than by an engineering training.

In order to introduce any considerable amount of mechanical engineering in the chemical courses it is necessary to eliminate something that we have there now; and the question is a very pertinent one, What kind

of instruction can be best spared? By two of the speakers analytical chemistry has been emphasized as especially important, a subject to which already by far the larger part of the available time is devoted in most chemical courses. I myself consider it a question whether this can not be reduced to a considerable extent in the case of chemists preparing for positions in the works rather than the laboratory. Another question that may, perhaps, be worthy of consideration is whether the modern languages to which a very large amount of time is devoted in most of the college courses are actually made use of to any considerable extent by manufacturing chemists.

Professor H. P. Talbot.

We can not probably hope to transform the student into a chemist and an engineer in the same four years, but we can hope, I think, to turn out a good chemist—a man fundamentally trained, at any rate—and at the same time to give him so much of the fundamental principles of engineering that he will at least know what a mechanical engineer is talking about and know what he ought to be expected to do. That is a good deal in itself.

As to what shall be taken out of our chemistry courses to make a place for these other subjects, there must always be a certain amount of sincere difference of opinion. While analytical chemistry is the yard-stick by which the chemist generally measures his practical attainments, it is possible, I think, that we sometimes make a mistake in teaching analytical chemistry in a too abstract way. I am hopeful that, as time goes on, we shall be able so to arrange our courses that we can connect analytical chemistry in the mind of the student more closely with the scientific or industrial problems to which it is to be applied, and in this way can stimulate his interest and develop his ingenuity. If a change of this sort will produce a graduate with greater power to apply his knowledge and technique promptly and practically, the time spent upon analytical chemistry will be fully justified.

Dr. Wm. Jay Schieffelin.

I want to say a word in answer to the questions which Dr. Noyes has put—first, should less time be devoted to analytical work; and second, are the languages important?

Most of the industrial processes are elaborations or applications of methods used in analysis; therefore, the technical chemist should know the methods. It is very hard to-day to get a man who is a good analyst, upon whose analysis you can entirely rely. If he must make an analysis which he has not made before, he takes a book of selected methods and goes through it, but his results are not satisfactory. I think it is vitally important that the man should be a trained analyst. It is the hardest thing in the world to have a mineral accurately analyzed to-day and there are very few men in the country who can make an analysis of a new mineral from which its formula can be deduced. But what interests the chemist in the technical laboratory is improvement in processes and apparatus more than in minute accuracy of results; moreover, in any technical laboratory there are comparatively few varieties of analyses being made. It seems to me that the German language is immensely important, because the German works, Beilstein and Dammer, are to-day the chemist's bibles, and contain nearly everything on organic and inorganic chemistry which he wants to learn about, and they haven't their parallel in the English language. It is, therefore, very important to have a knowledge of the German language, and I do hope there will be no at-

tempt to reduce the amount of time given to quantitative analysis.

Dr. Hugo Schweitzer.

Until now we have been a happy family and I hate to sound the discordant note. I am absolutely against the introduction of chemical engineering in the education of chemists and want to restrict the same to pure chemistry. You have heard from Professor Chandler and from Professor Noyes and the other gentlemen who are teaching at our universities and colleges that it is impossible to make a chemist and a chemical engineer in four years. This is not to be wondered at, as Mr. Herreshoff stated in his paper, and it was this that struck me most, that chemical engineering embraces more kinds of engineering than any other branch of engineering. Now, since he, the most successful, the most ingenious, the most prominent chemical engineer in this country, has been able to master both sciences, he thinks that we average people of little brains and little minds should also succeed. Gentlemen, the proof of the pudding is in the eating. Let us be open and frank! What have American chemists originated in chemical manufacturing? You will find that we have been pioneers in only a very few instances. It is true we manufacture acids and alkali just as well and perhaps better than they do in Europe, but, as I say, we have been pioneers only in a few things, and the reason for it is in our method of education. Who asks that we should be both chemists and engineers? Do we chemists ask for it? No, we have trouble enough with chemistry. Do the teachers of chemistry ask for it? No, because they tell us to-night that it is impossible for them to convert their students into chemists and chemical engineers. You remember Dr. Noyes said that 'to-day chemical science requires as much detailed knowledge as did all sciences together fifty years ago.' Do you think that with such a broad field we can also master chemical engineering? Most decidedly not.

It is the manufacturer who asks that we should be both chemists and chemical engineers. In my opinion, the education of the chemist, gentlemen, is entirely a secondary question. As far as they are not educated chemically, it is the employers of chemists who need education. They engage a chemist, and paying him the generous salary which we chemists are wont to get, they think he ought to be a chemical engineer besides. What the manufacturers ought to do is: they should take the graduates from the universities as they are educated in pure chemistry and train them in their works at their expense during one or perhaps two years to become technical chemists and technical engineers. So, gentlemen, I urge upon you most sincerely to abandon the idea of educating chemists to be also chemical engineers, and now let us all work for the education of the chemical employer and the capitalist.

Mr. Maximilian Toch.

A student can study languages before he enters into his course of chemistry. German is essential, but French is not. When a student is admitted to college he is about seventeen years of age and he should then have a fundamental training in mathematics and languages; in fact, at the age of seventeen a student can be fairly well trained in elementary chemistry and in mathematics and drawing, so that the four years at college can be applied to chemistry, physics and electricity.

My suggestion would be that the colleges invite men to lecture who have been successful in manufacturing industries and they naturally can impart knowledge to students such as a professor is not expected to have.

The college laboratory is totally different from a factory. Any student can make an ounce of a material, but when it comes to multiplying that by three thousand technical education is necessary.

PROFESSOR M. T. BOGERT.

It appears to me that the employers of technical chemists really want two kinds of chemists. In the first place, they need what may be called technical directors; men who are trained more thoroughly on the mechanical side than on the chemical side; who understand the handling of both men and machinery and who know in a general way the chemical processes to be carried out; and secondly, scientifically educated chemists. The training of these two classes of chemists, it seems to me, is quite different. The man who has to do with a particular chemical problem and work it out in the laboratory needs a very thorough and highly specialized training in chemistry. Engineering is not necessary. The value of the results accomplished have been placed too much, in my opinion, to the credit of the technical director. The man who is working in the laboratory, the man behind the guns, is the man who has accomplished results in Germany as well as in this country. I think the progress in Germany in technical chemistry has been due largely to the work in the research laboratories by men who have no engineering training, and I plead with the employers for recognition of the work of the men in the laboratories and for greater patience in their dealings with them, and for a more enlightened policy in establishing research laboratories, for, in my opinion, it is only through such establishments that the American chemist can hope to compete with the German chemist.

MR. W. H. NICHOLS.

The young man who goes to college to get his technical training should determine whether he is going to use it in the realm of pure research or whether he is going to be a chemical engineer. The mechanical engineer can not take the place of the chemical engineer, as he goes to the other extreme. We have already the purely scientific chemist and the engineer; between the two we have the technical chemist or chemical engineer and there is plenty of opportunity for him.

It should be remembered in this connection that a college course is simply a foundation, on which the further education is to be built in after life; for it is not possible to furnish the thoroughly educated man in four or even in five years.

SCIENTIFIC BOOKS.

Skew Frequency Curves in Biology and Statistics. By J. C. KAPTEYN, ScD., Professor of Astronomy at Groningen. Published by the Astronomical Laboratory at Groningen. Groningen, P. Noordhoff. 1903.

This paper is almost unique in that it attempts to be at once a popular presentation of statistical methods and a mathematical derivation of a new theory regarding skew frequency curves, thus attempting to 'benefit all students of statistics' by his ideas. It is only necessary for the non-mathematical reader to take his mathematics for granted and apply the formulæ deduced, while the mathematician need not waste much time over the first ten paragraphs.

The author mentions how Francis Galton has shown that important biological conclusions may be derived from a discussion of the normal curve, and deplores the fact that most of these deductions can not be extended to the skew curves of Quételet and Pearson. This, he says, is due to the purely empirical nature of these curves; they furnish a mechanical representation of the data without having any real and vital relation to them. The advantages claimed for the new theory are: "(*a*) It assigns the connection between the form of the curves and the action of the causes to